Workshop on soil management of cocoa

October 2011

Importance of soil fertility management for sustainable cocoa production

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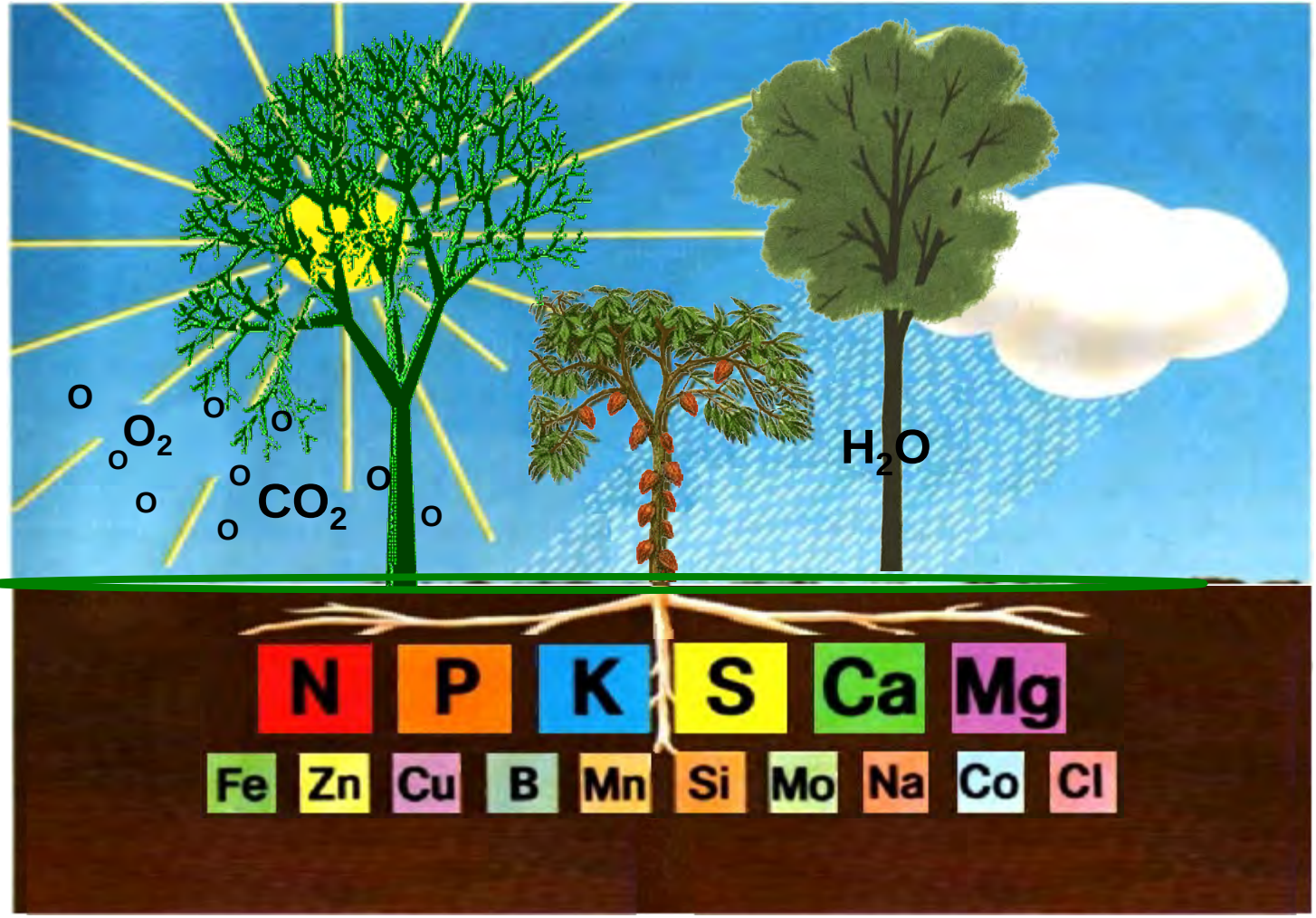
UR: Performance of Tree-crop-based systems

Like any other crop, cacao-tree needs to feed

Organic matter

Soil nutrients



Nutrition of cacao depends on environment

Different environments (climate, soil pedological profiles, etc.)

➔ different soil nutritional potentials

Nutrition of cacao depends on associated trees

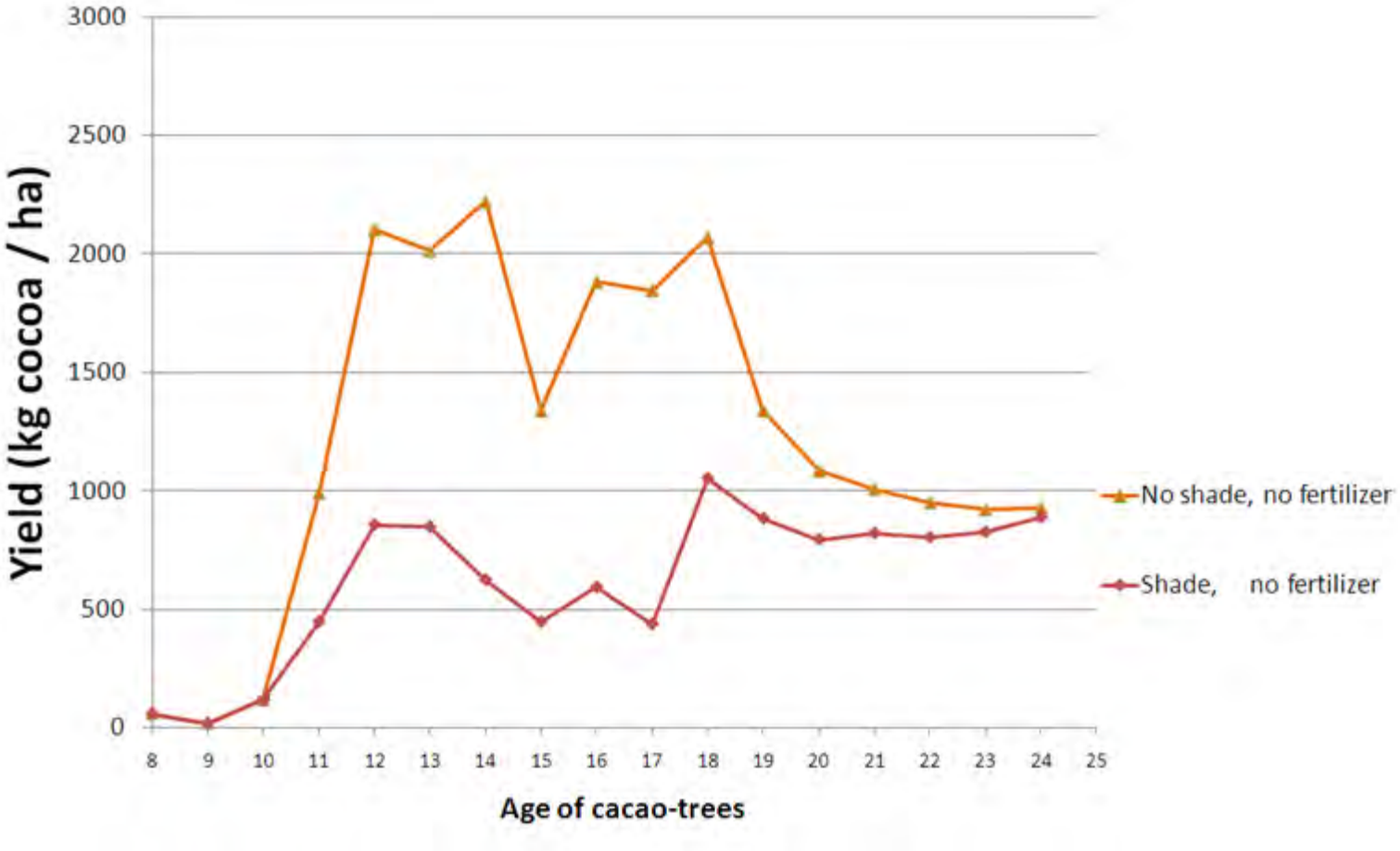
- Associated trees can be responsible of:
  - Nutrient improvement:
    - e.g.: an **increase** of 16 % N in litterfall was observed under leguminous trees as compared with non N_2 fixing shade trees (Alpizar *et al*., 1986).
  - Nutrient competition:
    - e.g.: a **reduction** of soil available P was observed under cacao associated with *Milicia* (Iroko) (Isaac *et al*., 2007).

Different tree associations and crop densities and shade

➔ different soil nutritional potentials

Nutrition of cacao depends on Management practices

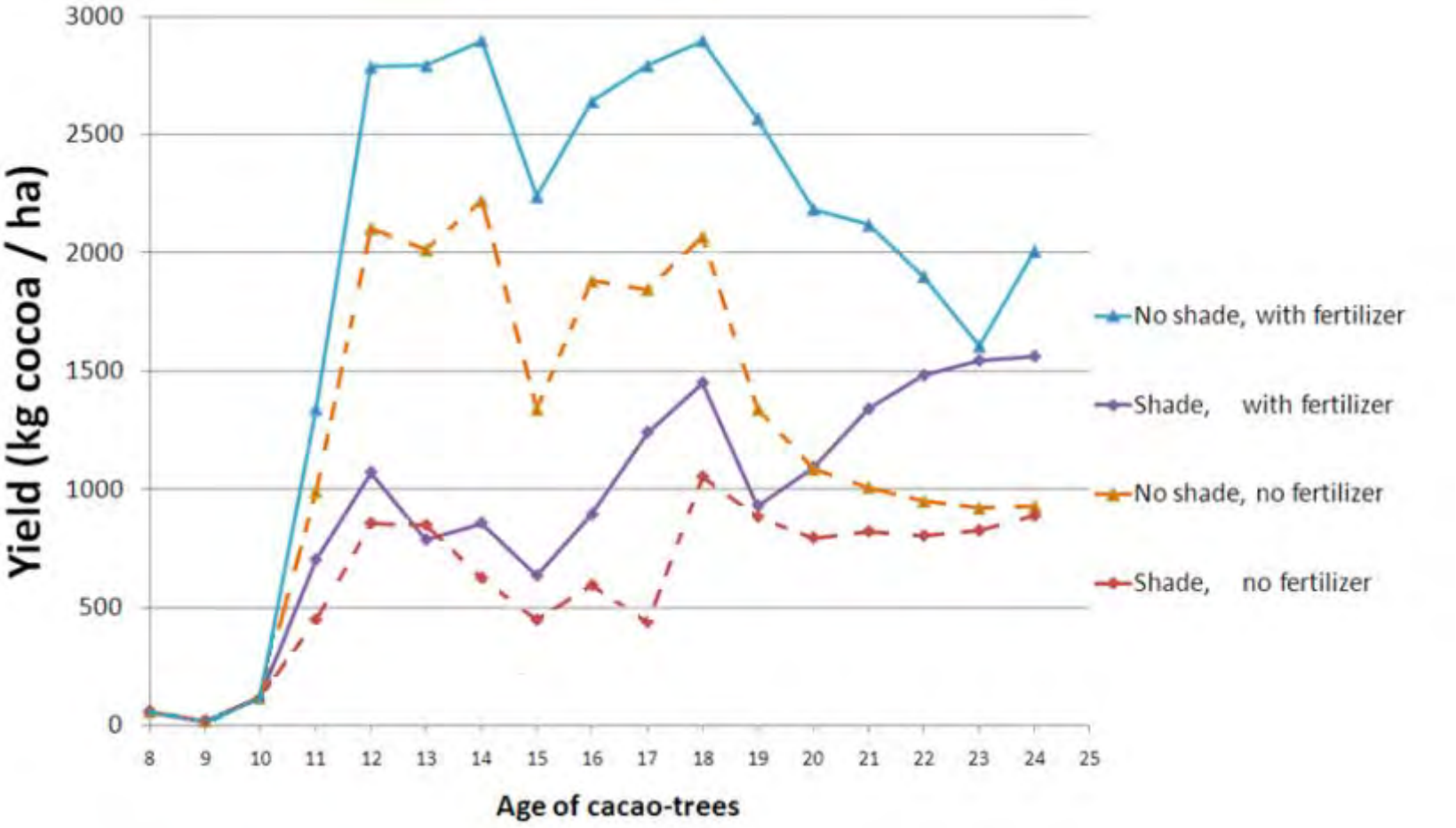
Impact of shade on cocoa yield



Source: Cunningham and Arnold (1962), Ghana

Nutrition of cacao depends on Management practices (Cont'd)

Impact of fertilizer on shaded and unshaded cocoa



Source: Cunningham and Arnold (1962)

Nutrition of cacao depends on Management practices (Cont'd)

Example of phosphorus depletion in unfertilized cocoa plots

Amelonado		Available P_2O_5 (ppm)	
		1957	1972
Shade	No fertilizer	24,1	0,7
No shade		27,3	0,9
Shade	With fertilizer	25,5	21,2
No shade		22,5	19,3

P deficiency (*below 15 pm*)

15 years

Different farming ➔ different soil nutritional potentials

Source: Tafo fertilizer and shade trial (Ghana)

Impact of fertilization at farm level

Fertilization can be profitable at farm level.

Application of TSP + KCl fertilizer applied from 1990 for four years.

Cocoa: on-farm response to fertilizer, Ashanti region

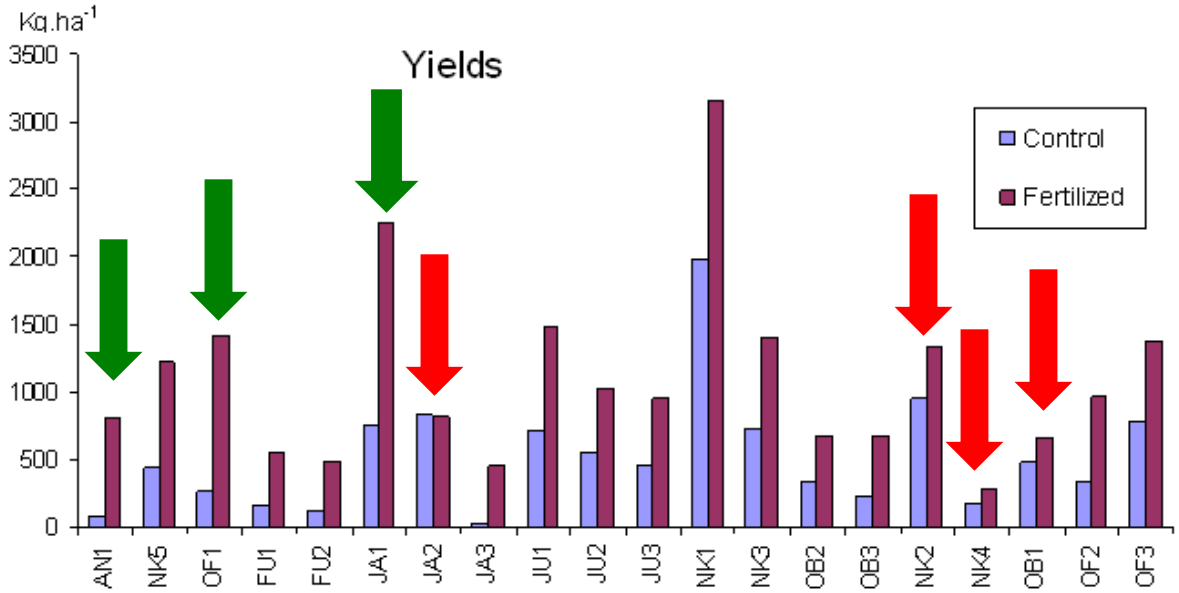
Treatment	Average yield (kg dry beans /ha)			
	1991/92	1992/93	1993/94	1994/95
Fertilized	807	1 033	1 124	1 457
Unfertilized	499	517	520	705
Benefit from fertilization:	62%	100 %	116%	107%

Results show the average effect of P and K over 20 farms tested on yields.

Source: On-farm trial. Appiah *et al.*, 2000

Impact of fertilization at farm level (Cont'd)

The benefits from a same fertilizer are different for different farms



Some farms get high benefit;

Some farms get low or no benefit.

Adapted from Appiah et al. (2000)

Intermediate Conclusions

Fertilization can improve yields.

But every farm has different local soil fertility, due to different:

- ✓ Environment,
- ✓ Climate,
- ✓ Associated crops,
- ✓ Soil pedology,
- ✓ Management,
- ✓ etc.

➢ Fertilization must be adapted to actual and current local soil conditions.

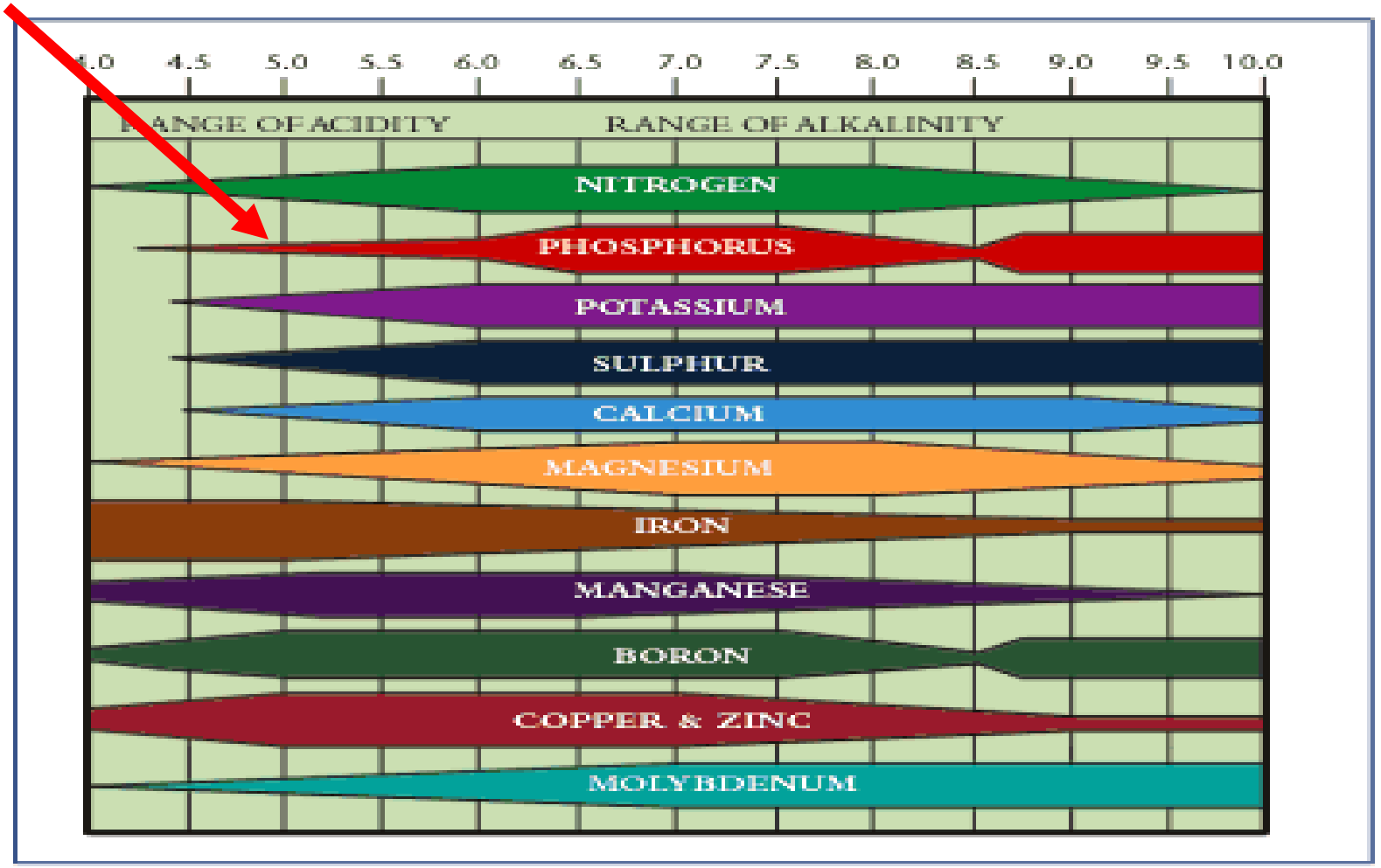
Some principles of mineral nutrition

adapted to cocoa cultivation

Soil nutrient **Availability** depends on soil pH

Availability of most nutrients is reduced below pH 6

Particularly phosphorus



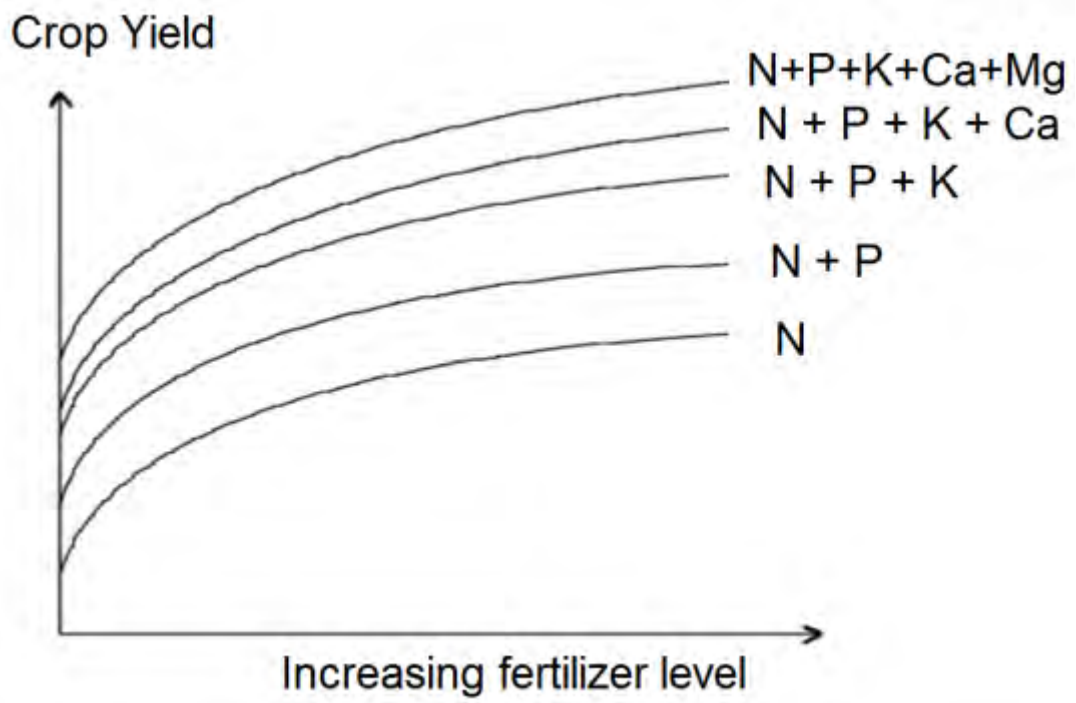
Source: *www.fertilizer.org*

Soil nutrient **Efficiency** depends on soil pH

Soil pH	Nitrogen %	Phosphorus %	Potassium %
4.5	30	23	33
5.0	53	34	52
5.5	77	48	77
6.0	89	62	100

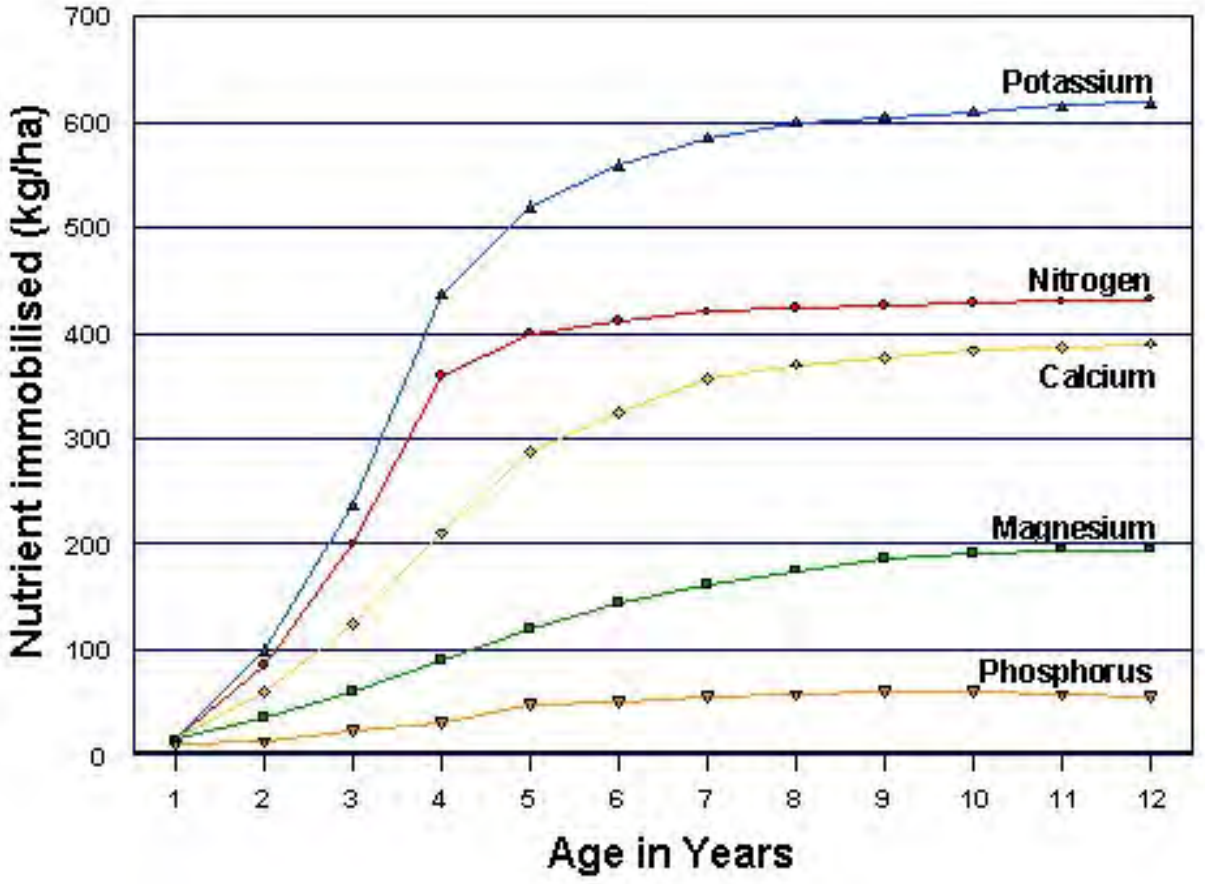
Efficiency of each nutrient is dependent on others

When a nutrient is added, and others remain low, they will become the limiting factors. First P, then K, etc.



- Ratios between nutrients must be kept to avoid wastes.

Nutrient uptakes grow with age



Adapted from Thong et Ng (1980)

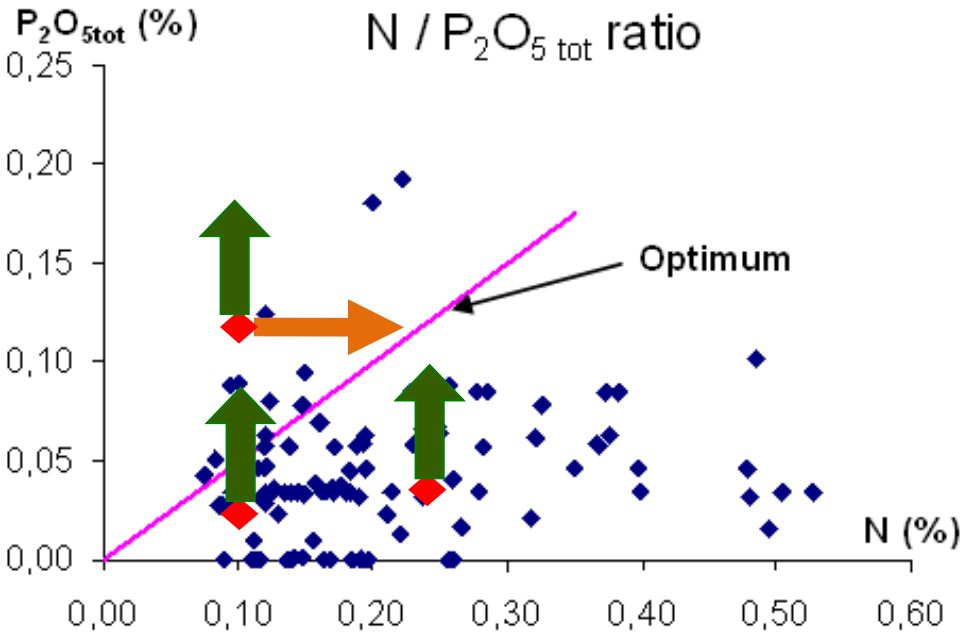
Nutritional requirements are **specific** to each species

- **For cacao**: Nutrient requirements were determined from long-term field fertilizer trials on young and mature cocoa plantations supplemented with pot experiments.

- The soil diagnostic method for cacao takes into account:
  - Thresholds level of each of the major soil nutrients;
  - Ratios between nutrients. Particularly:
    - N / P
    - N / Exchangeable bases
    - K, Ca, Mg (*optimum = 8 % – 68 % – 24 %*)
  - pH (*best if > 5*)
  - Base saturation (*best if ≥ 60 %*)

Source: Jadin, CCT, 1975

Example of the importance of N : P ratio on nutrient efficiency



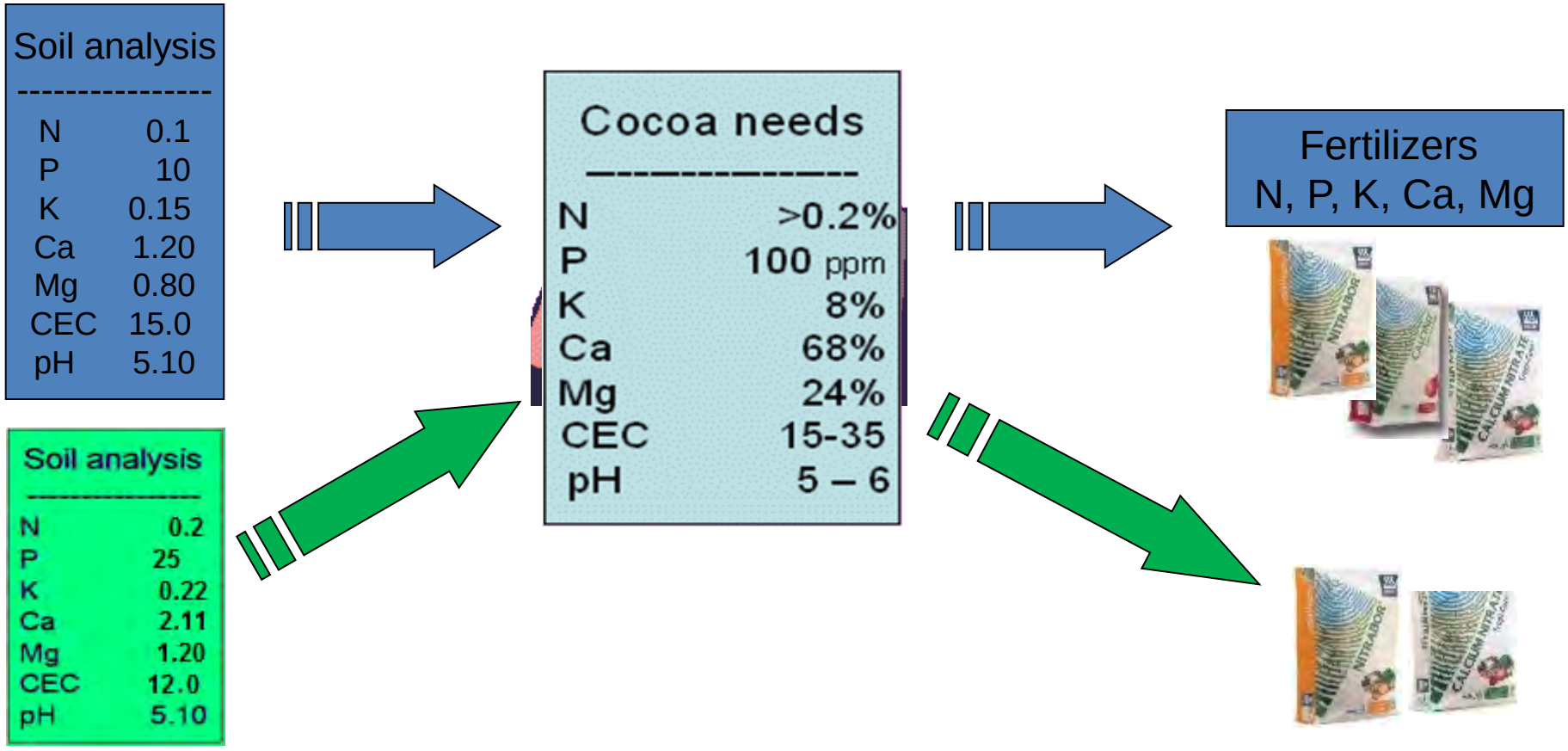
Dots below the optimum line show cacao plots where P is required;

Dots above the optimum line show cacao plots where N is required.

Determination of fertilizer (formula & dose) for cocoa-trees

Conversion from actual soil requirements (soil analysis) to fertilizer formulae and doses requires expertise and scientific knowledge.

To help experts, we developed a computer program.



Soil Diagnostic Step 1:
Calculation of soil nutrients

The Soil Diagnostic computes the amounts of major nutrients (N, P, K, Ca, and Mg) based on their levels in the soil and the ratios between them.

- A foliar diagnostic is sometime necessary to calculate the levels of minor nutrients (Zn, B, Mn) and suflur.
- It was developed in research stations and adapted to different ecosystems (Snoeck *et al.*, 2006 and 2007) before being used in industrial plantations and farms (*expertise*).

Country		Ghana			
Code		Sprie NK3 2006 Sa			
Clay + fine silt	(%)	4		Expected values after fertilization	
Carbon	(%)	1,67	C/N = 12,3		
Nitrogen	(%)	0,136			
P total	(ppm)		N / P_2O_5	-	
P available	(ppm)	0,85		75,0	
K	(meq%)	0,295	10,0%	1,126	8,0%
Ca	(meq%)	1,485	50,3%	9,574	68,0%
Mg	(meq%)	1,170	39,7%	3,379	24,0%
Al 3+	(meq%)				
C.E.C.	(meq%)	35,200			
pH	(H_2O)	4,70			
Sum of Exch. Bases		2,95		14,08	
Base Saturation		8,38		40,00	
∑ (exch. Bases) / N		6,72		14,93	

Comments

Test (exch. B.) / N => increase bases *After modif. => increase nitrogen*

N / P_2O_5 (optimum = 1,5)

Soil Diagnostic Step 2:

Replacement of nutrients removed through harvest

1 ton of dry cacao beans with 1.4 tons husks will export from the field

	N	P_2O_5	K_2O	CaO	MgO
- Beans	21	9	11	1	4
- Pod husks	14	4	68	7	7
Total removed	**35**	**13**	**79**	**8**	**11**

= 146 kg

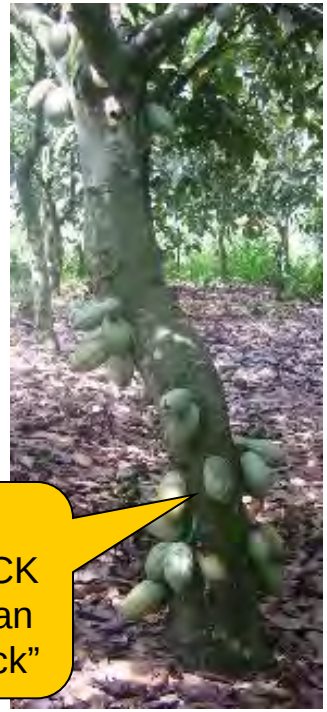
Because:

BEANS: leave the farm.

HUSKS: often remain outside the cocoa field

- ✓for sanitary reasons (*Black Pod disease*)
- ✓for by-product preparations (soap, etc.)

- Non-replacement of nutrients on a regular basis:
  - reduce nutrient levels in the soil,
  - compromises cocoa survival.



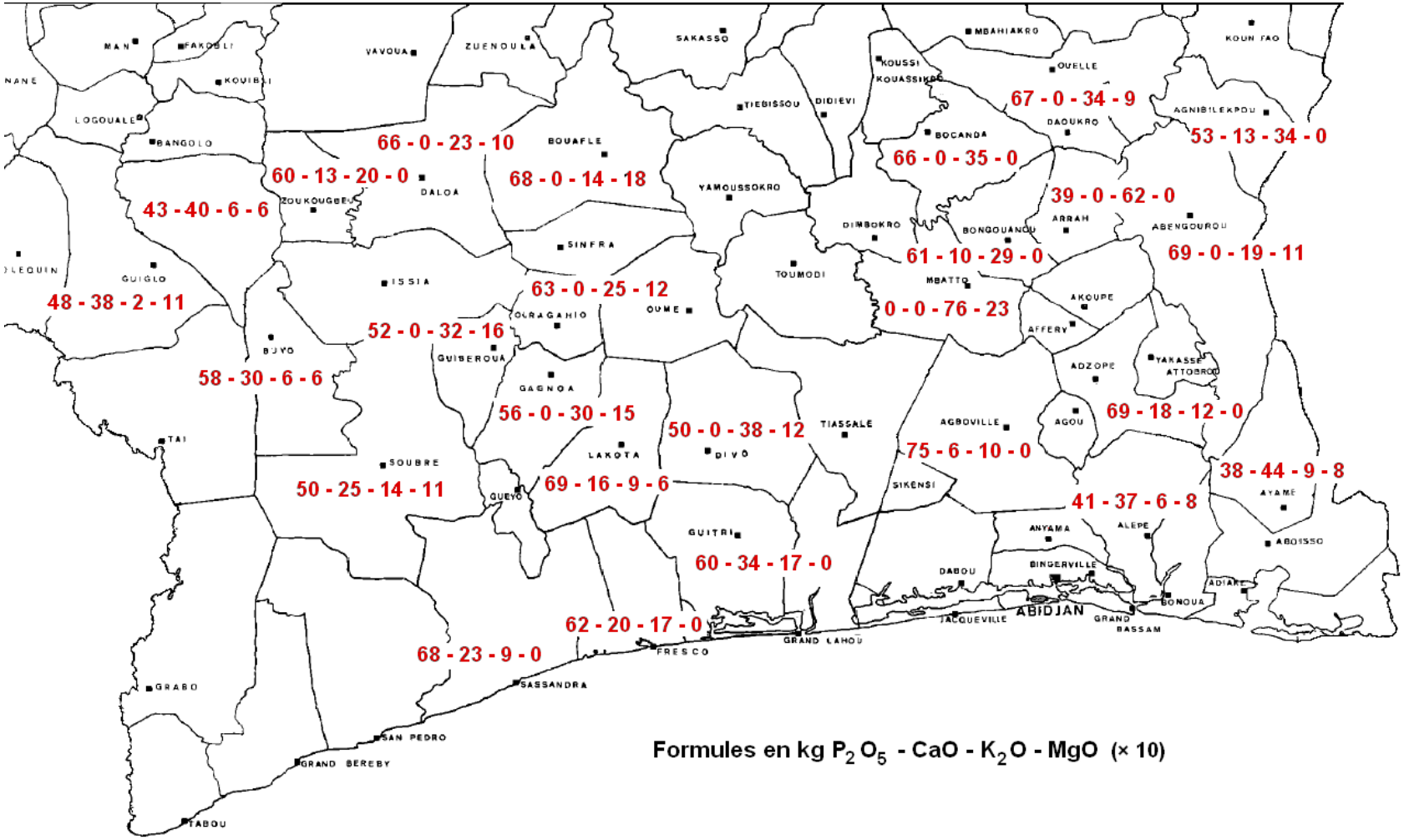
Soil diagnostic: Recent results

- The soil Diagnostic was used in the sustainable and competitive cocoa network namely (East to West):
  - Cameroon: *IRAD (in partnership with Univ. Yaoundé 1 and Dschang)*,
  - Nigeria: *CRIN & FUTA*,
  - Togo: *ITRA*,
  - Ghana: *CRIG & UG*,
  - Côte d'Ivoire: *CNRA*.

- In Central Cameroon, first results have confirmed the sustainability of agroforestry systems based on cocoa for the maintenance of soil fertility (Snoeck *et al.*, AFS, 2009).

Soil diagnostic: Recent results (cont'd)

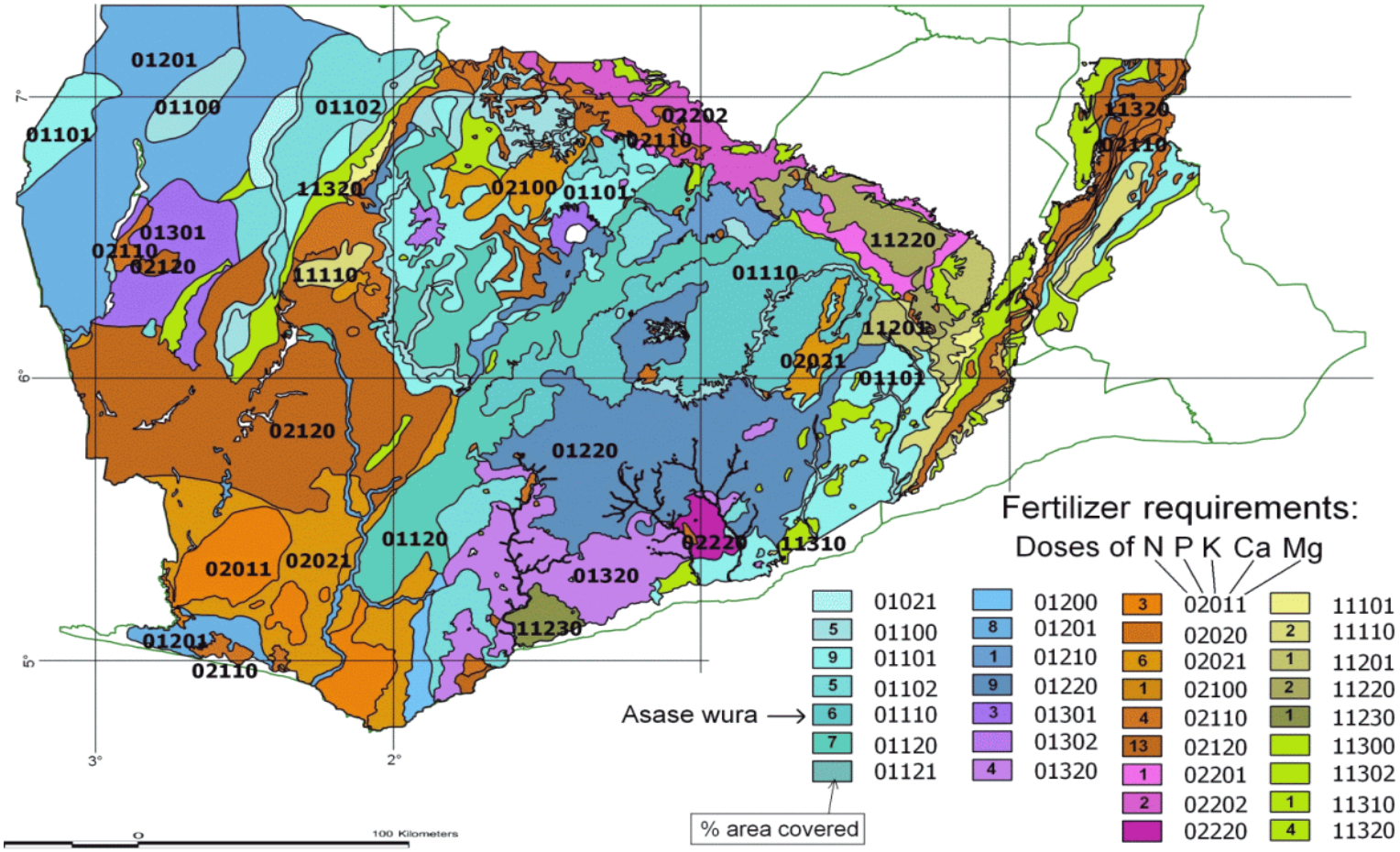
In Côte d'Ivoire, the soil diagnostic model was used to build a map of the fertilizers formulae per department.



(Source: Jadin, 1975)

Soil diagnostic: Recent results (cont'd)

- In Ghana, the Soil diagnostic has been combined with a geographic information system (GIS) to initiate a process of precision agriculture and optimization of fertilizer applications.



(Source: Snoeck *et al.*, WAJAE.org, 2010)

Conclusions

- Soil fertility is declining in cacao plantations due to the consumption of nutrients not replaced.
  - Nutrients are taken from the fields and not replenished.
- Cocoa production without proper fertilization is not sustainable for Farmers, Environment and Consumers.
- The use of fertilization requires good crop management for better nutrient availability.